Canadian Validation of AMSR-E Snow Cover Products

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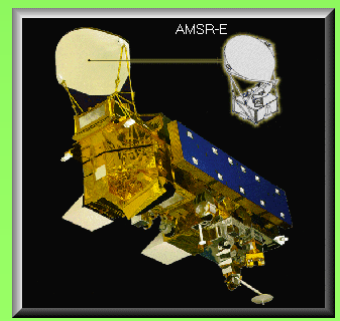
Joint AMSR-E Science Team Meeting, September 13-15, 2005, Honolulu



CRYSYS – The CRYosphere SYStem in Canada

- **NASA EOS Interdisciplinary Science Investigation (IDS team) since 1990; renewed in 1995, 2000 and 2003 (*www.crysys.ca*)**
- **MSC-led, 20+ co-I's and team members (gov't, university, private industry) distributed across country (funded by MSC, CSA)**
- **Investigate variability and change in cryospheric variables and the role of the cryosphere in the climate system**
  - **→ Development of satellite-based capabilities**
  - **→ Evaluate/develop cryospheric products/information from EOS sensors**
- **Outreach: *State of the Canadian Cryosphere (www.socc.ca) and Canadian Cryospheric Information Network* (*www.ccin.ca*)**
  - **→ access to cryospheric information and data sets generated by CRYSYS project**

Snow

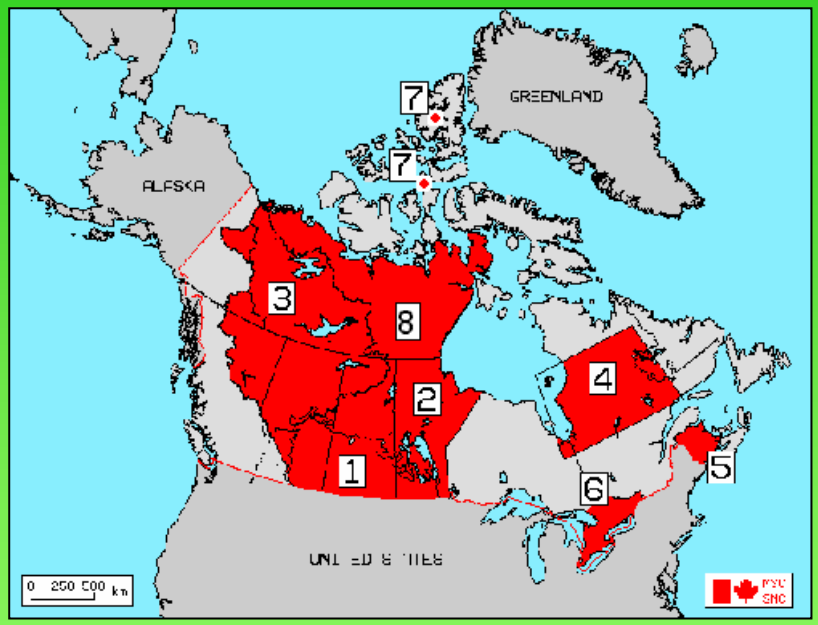
Lake Ice

Sea Ice

Glaciers/ Ice Caps

Permafrost/ Frozen Ground

CRYSYS Passive Microwave Snow Cover Research



Study sites:
- [1] Southern Prairies (agricultural)
- [2] Boreal Forest (forest)
- [3] Mackenzie Basin (forest, tundra)
- [4] Central Quebec (taiga)
- [5] New Brunswick (dense forest)
- [6] Southern Ontario (agricultural, forest)
- [7] Arctic Islands (tundra)
- [8] Nunavut (tundra)

Main objective:

- develop, validate and refine empirical and theoretical algorithms of snow cover properties in varying climatic regions and landscapes of Canada using passive microwave data
- focus on SWE algorithm development and validation (SSM/I)
- satellite, airborne and ground-based radiometers
- field campaigns
- information products for operational agencies (e.g. flood forecasting, hydro-power, weather prediction)
- time series for cryosphere-climate research (SMMR, SSM/I)
- collaboration with university research partners

CRYSYS Validation of AMSR-E Snow Cover Products

MSC microwave radiometers on NRC Twin Otter

1) *Airborne/field validation campaigns*

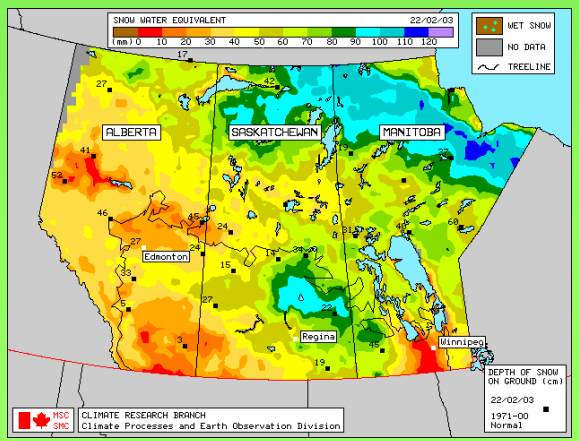
- Acquisition of airborne microwave radiometer data and ground-based measurements to support:

- validation of satellite retrievals
- algorithm refinement/new development

In-situ measurements

2) *Regional snow surveys*

- Targetted to specific landscape environments
- ground-based measurement transects over extensive areas



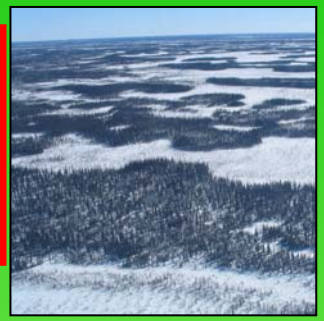
SSM/I SWE map

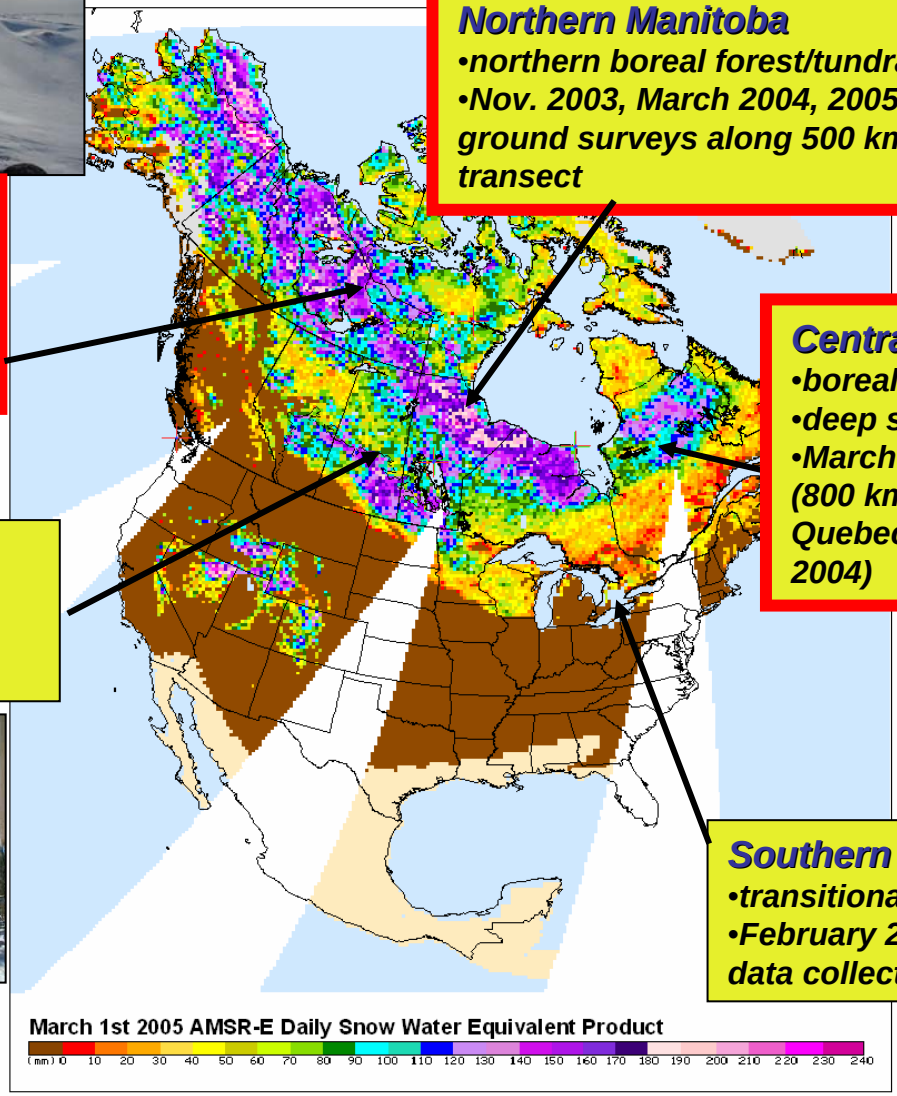
3) *Comparison of AMSR-E standard SWE products with SSM/I derived regional SWE maps*

AMSR-E Snow Cover Validation Campaigns

Northwest Territories
- *tundra snow, lake ice*
- *April 2004 – ground surveys*
- *April 2005 – aircraft/ground data collection*

Northern Manitoba
- *northern boreal forest/tundra*
- *Nov. 2003, March 2004, 2005 – ground surveys along 500 km transect*





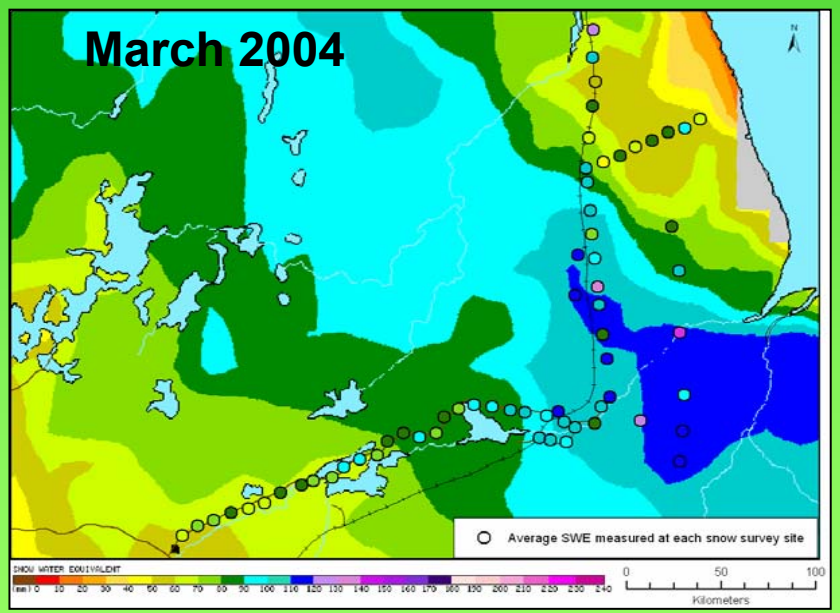
Central Quebec
- *boreal forest/taiga*
- *deep snow cover (150 mm+)*
- *March 2003 ground survey (800 km transect); Hydro Quebec snow surveys (2003-2004)*

Canadian Prairies
- *agricultural/boreal forest*
- *February 2003 – aircraft/ground data collection*

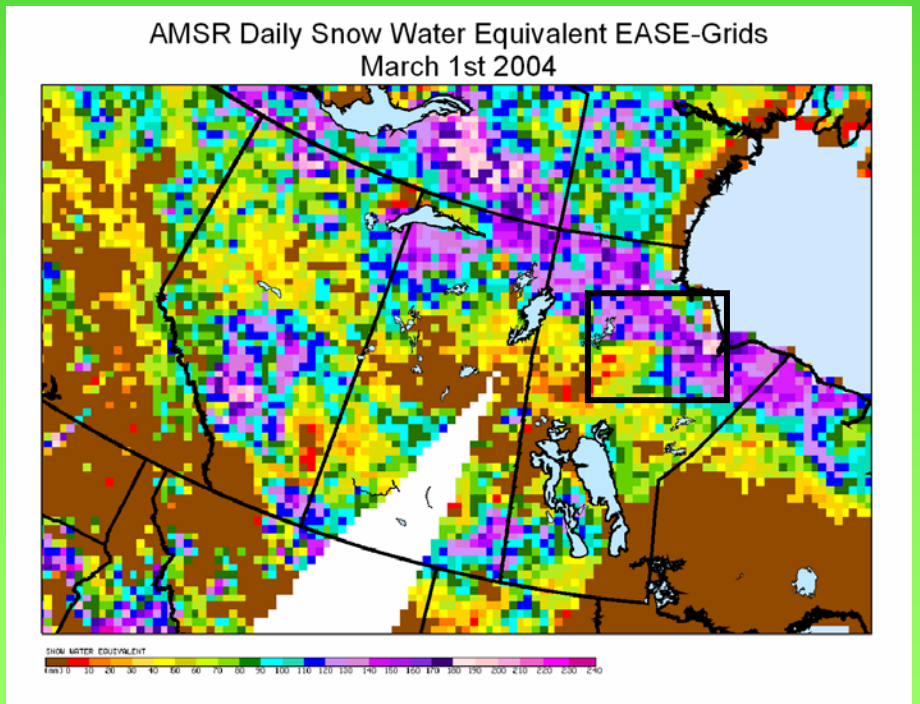
Southern Ontario
- *transitional snow cover*
- *February 2004 – aircraft/ground data collection*

AMSR-E Snow Validation Campaign: Northern Manitoba (March 2004)

- Ground-based snow cover measurements along 500 km transect from Thompson to Gillam to Churchill in northern Manitoba (vehicle and helicopter access)
- Focus on validating high SWE zone that has been persistent on SSM/I SWE maps – northern boreal forest to tundra transition



SWE measured by survey teams compared with SSM/I SWE map
→ground measurements range from 60-120 mm
→SSM/I SWE consistent with ground measurements over boreal forest, underestimation in tundra

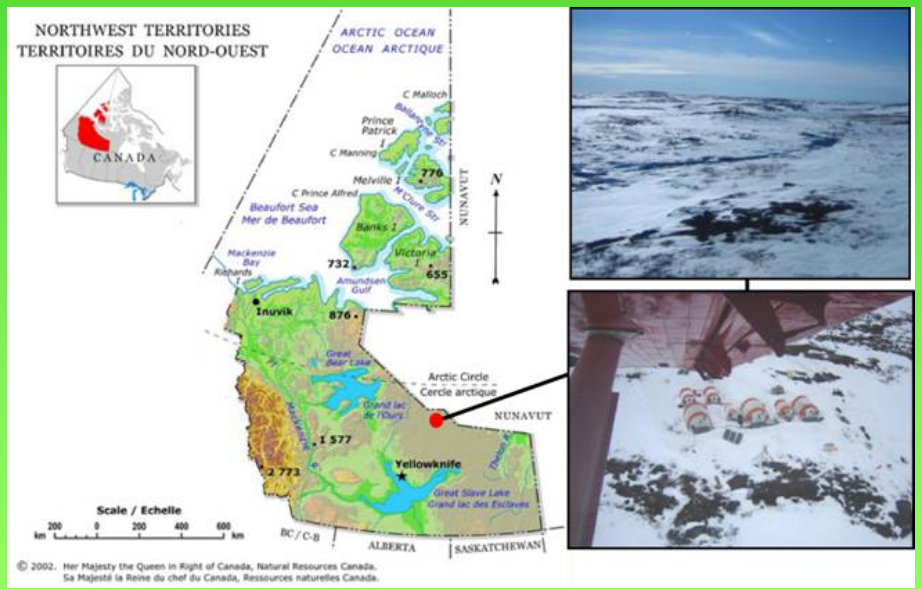


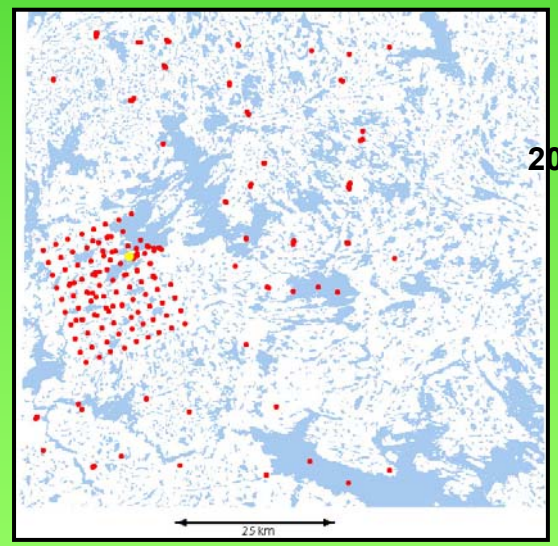
AMSR-E SWE over same zone range from 100-180 mm
→higher than ground measurements

Tundra Snow Survey Data

- Algorithms remain undeveloped and unevaluated for most tundra areas:
  - What are the topographic controls on SWE distribution and magnitude?
  - How do these integrate across large spatial domains?
  - What are the relationships between lake size/fractional area and snow properties, brightness temperatures?
  - Algorithm transferability across different tundra regions?

- Snow surveys conducted in the upper Coppermine basin during three seasons (2003-2005) to determine within and between grid cell variability in snow properties.





2004 sample sites

- Systematic passive microwave SWE underestimation evident in tundra environments due to factors such as high snow density and sub-grid resolution lake cover.

Survey	Arithmetic SWE	Lake vs Terrain Weighted	Areally Weighted SWE	SSM/I SWE
2003	123	115	104	79 mm
2004	196	176	127	49 mm
2005	115	106	100	73 mm

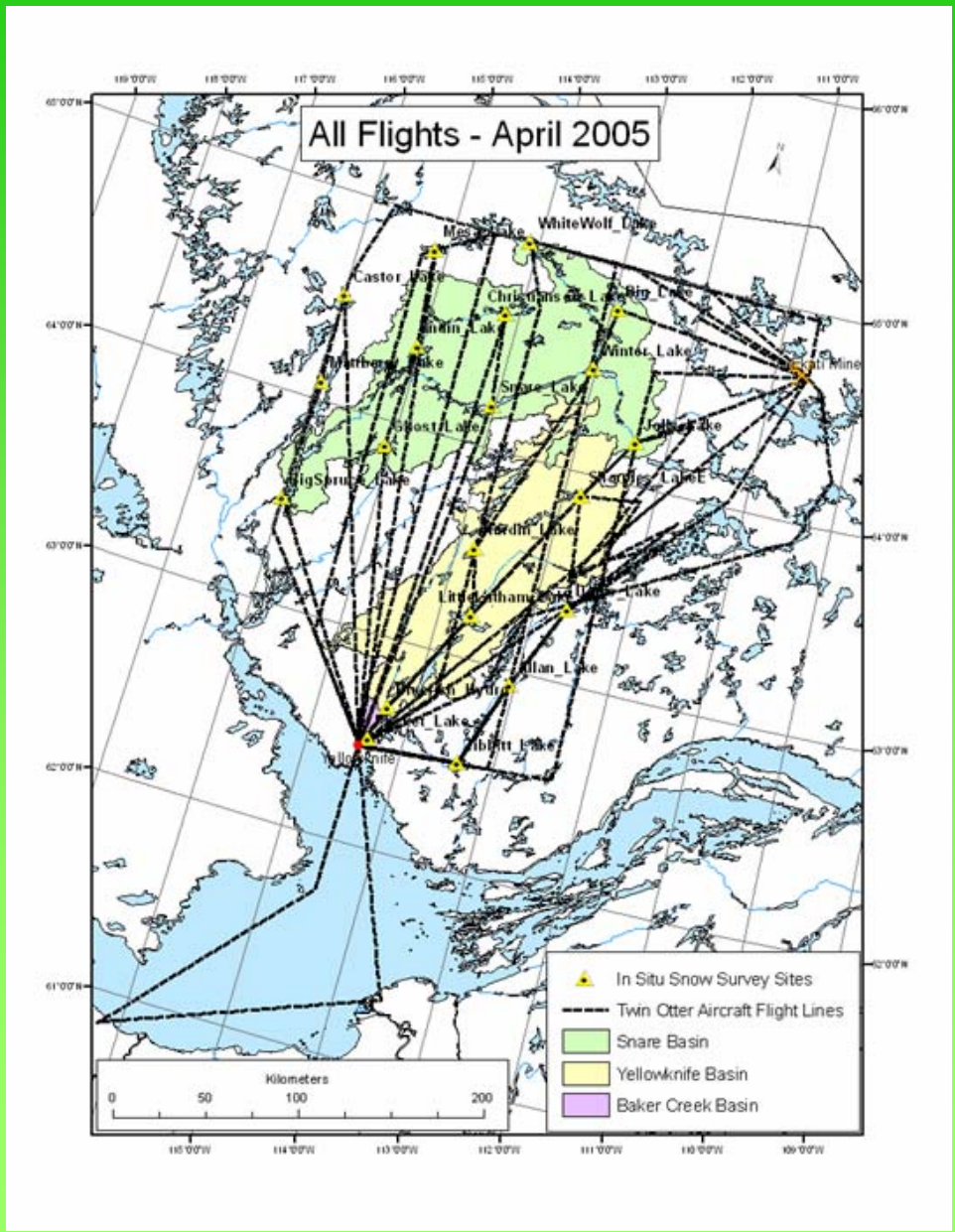
April 2005 Tundra Field Campaign

Airborne passive microwave surveys:

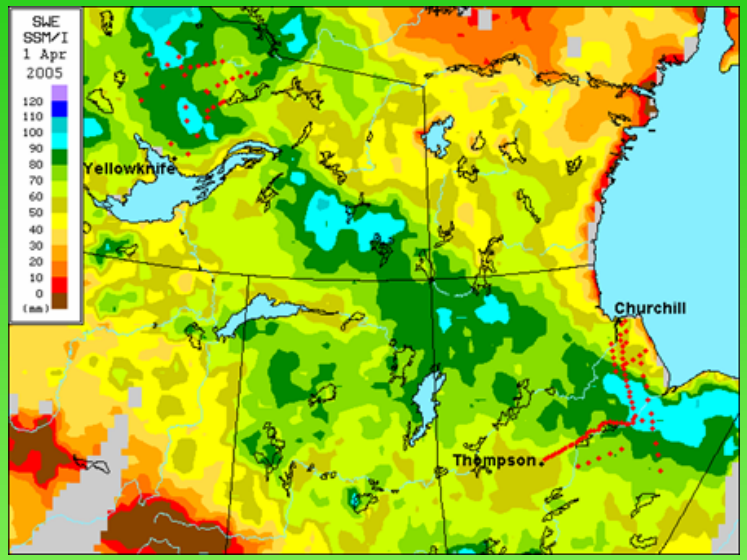
- Aircraft based in Yellowknife
- Flightlines:
  - Daring Lake (open tundra)
  - Snare/Yellowknife Basins (forested)
  - Great Slave Lake (ice thickness)

Other data acquisition:

- Ground-based microwave radiometers
- Snow surveys along flight lines
- Snow isotope sampling



2005 Regional Snow Survey Data – AMSR-E TB Analysis



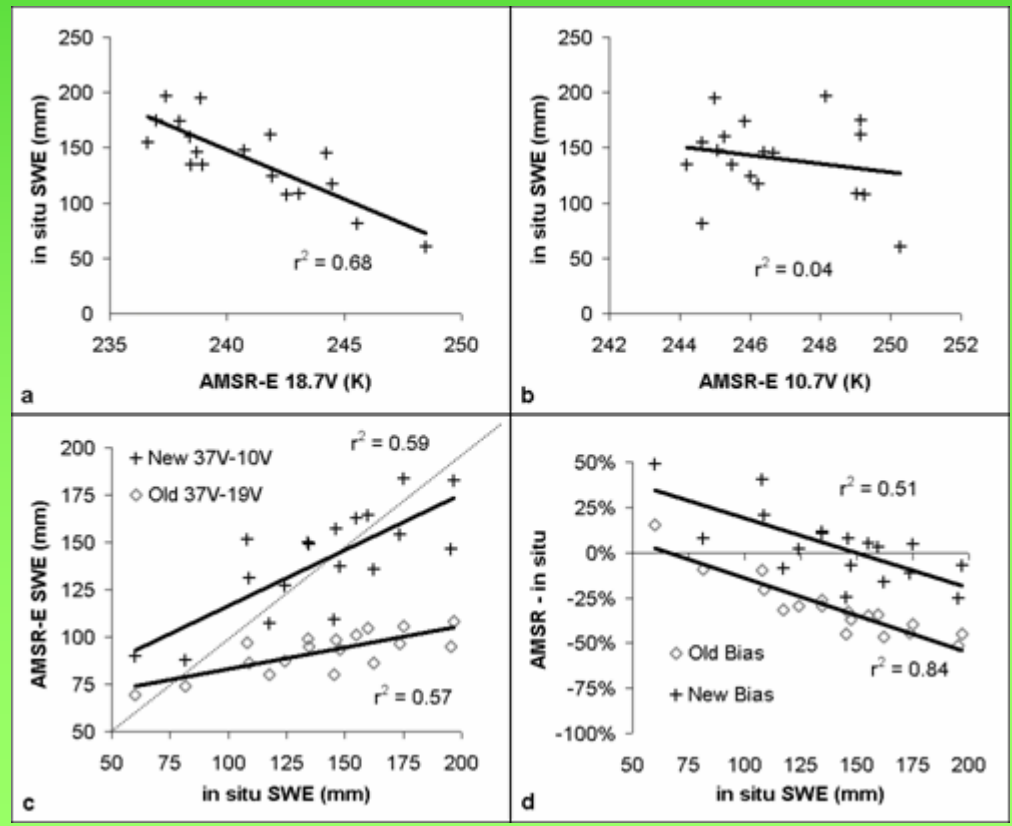
- Sites located in the Northwest Territories and northern Manitoba (also sampled in 2004).

- These datasets provide a comprehensive perspective on northern boreal snow cover from the Hudson Bay lowlands to the boreal shield north of Great Slave Lake – a region with an extremely poor historical conventional measurement record.

- Unlike 18.7 GHz, 10.7 GHz AMSR-E data are not sensitive to even the deepest snowpacks.

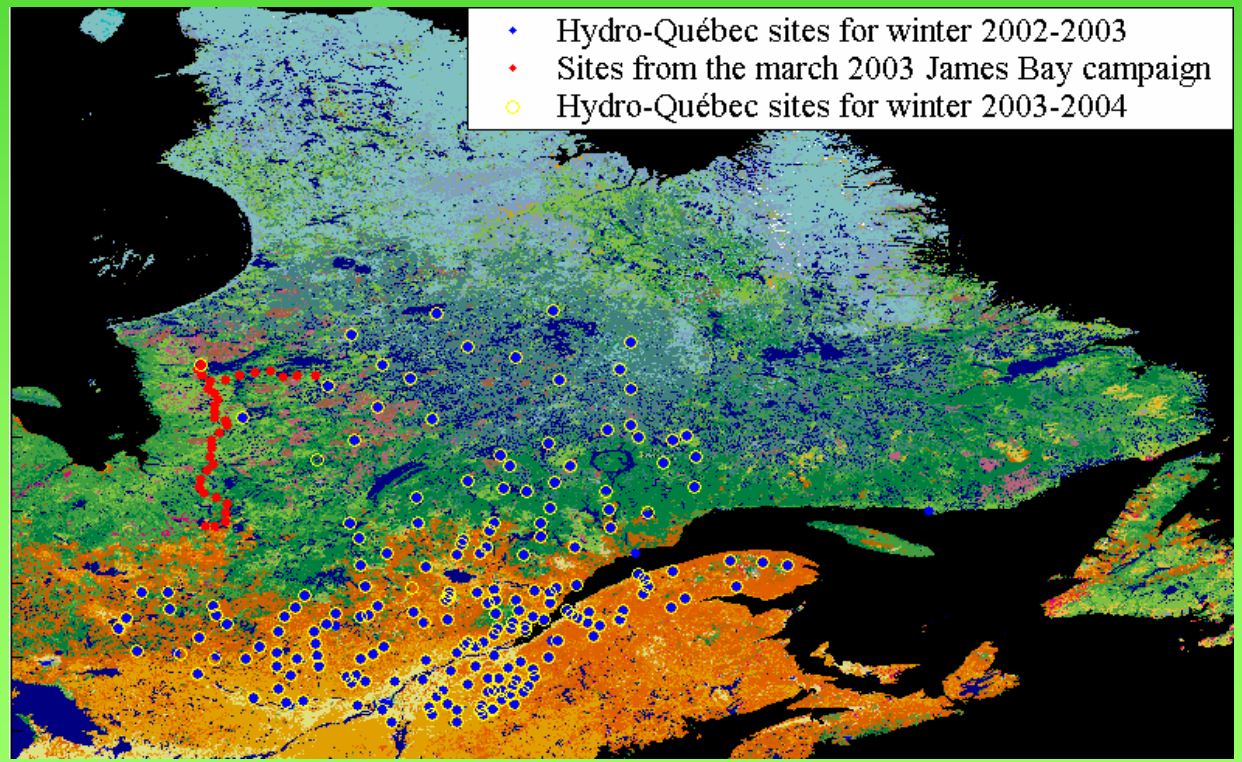
- Replacing BOREAS era coefficients with those calculated from the 2005 NWT campaign (36.5V-10.7V) results in SWE retrievals in better agreement with ground measurements.

- The bias characteristics are still linearly related to SWE magnitude, but to a lesser extent than the original MSC algorithm scheme; consistent SWE underestimation is less pronounced.



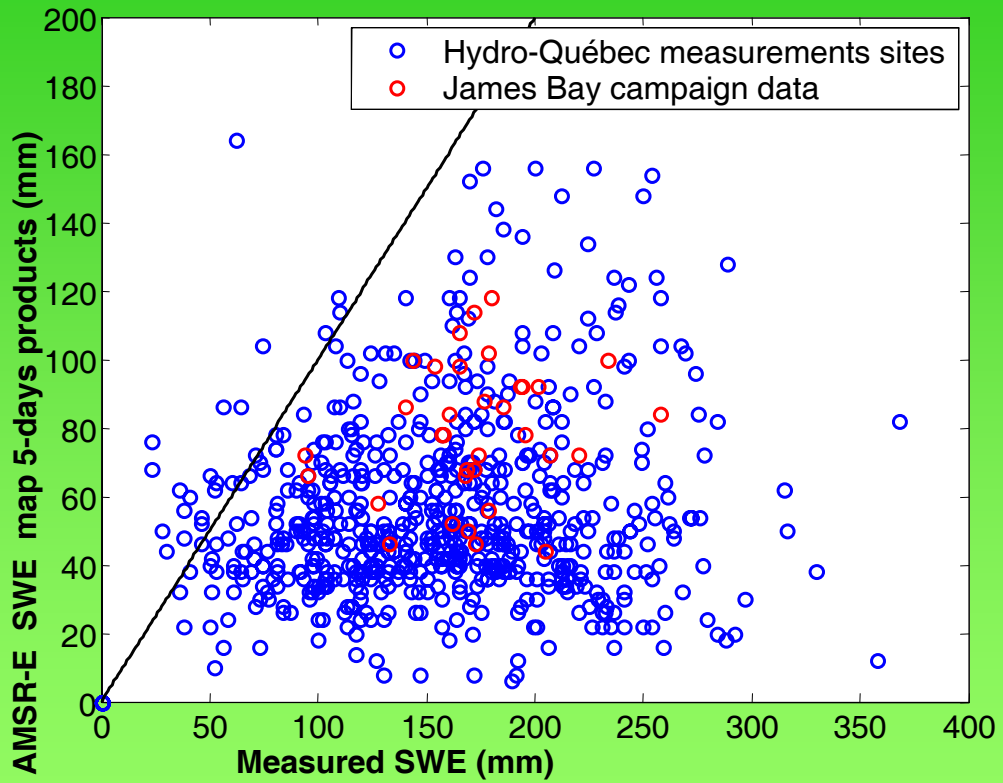
AMSR-E SWE Validation over Quebec

- **Evaluate AMSR-E snow water equivalent map product errors for the province of Quebec using snow survey data (U. Sherbrooke, Hydro Quebec)**
- **Investigate possible sources of errors and potential corrections**



Classification map used : Land Cover Map for North America in the Year 2000. R.Latifovic, Z.Zhu, J.Cihlar, J.Beaubien, R.Fraser. GLC2000 database, European Commision Joint Research Centre, 2003.

Quebec AMSR-E SWE Evaluation Results - Winter 2002-2003



Number of measurements: 1010

Temporal coverage: Jan. 15 to May 15

RMSE= 110 mm

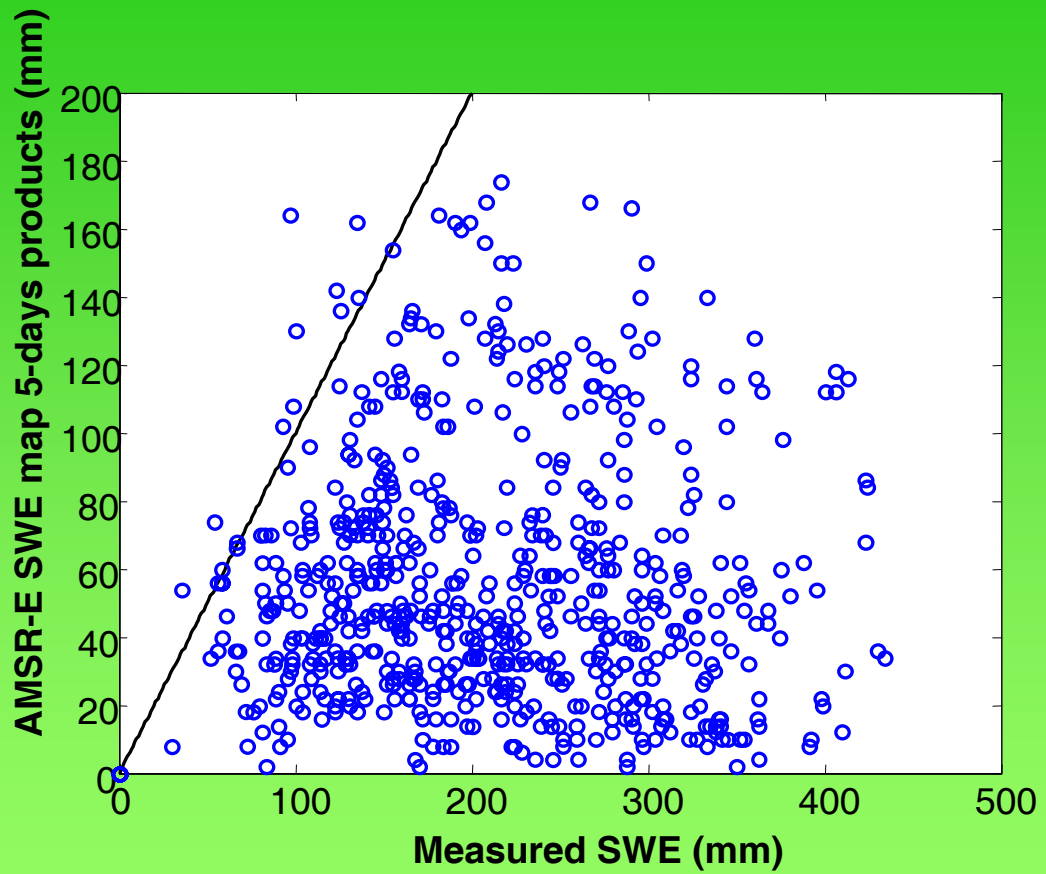
Bias = -88 mm

Mean SWE on the ground: 139 mm

Mean AMSR-E SWE (without the null values): 46 mm

- For error assessment the 5-day SWE map product was used because of better temporal coverage
- On 210 (20.8%) occasions the AMSR-E SWE algorithm did not detect snow (not indicated on the plot)

Quebec AMSR-E SWE Evaluation Results - Winter 2003-2004



Number of measurements: 960

Temporal coverage: Jan. 15 to May 15

RMSE = 175 mm

Bias = -146 mm

Mean SWE on the ground: 199 mm

Mean AMSR-E SWE algorithm (without the null values): 53 mm

- On 225 (23.4%) occasions the AMSR-E SWE algorithm did not detect snow although there was snow on the ground (not indicated on the plot)
- Higher RMSE could be linked to higher snow water equivalent mean on the ground

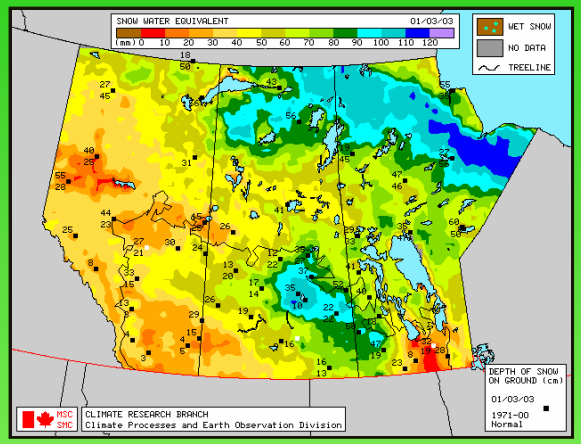
Possible Sources of Error in AMSR-E SWE - Quebec

- ***Grain size, density***
  - **AMSR-E SWE algorithm assumes a mean snow crystal of 0.3 mm and a snow density (ρ) of 0.3 g/cm^3**
  - **For Quebec mean ρ = 0.26 g/cm^3 in 2003 and ρ = 0.28 g/cm^3 in 2004.**
  - **Mean grain size for the James Bay campaign between the 4th and 11th march : 1.36 mm**

- ***Application of AMSR-E SWE algorithm is limited to snow depth less than one meter***
  - **Snow depth variation in Quebec : 19 % of the measurements in 2004 exceeded one meter but only 6 % in 2003.**

- ***In numerous cases, AMSR-E algorithm did not detect snow.***
  - **Most of this happened after the month of March, although 73.8 % of those sites had over 25 cm of snow**
  - **problem could be the wet snow detection algorithm (T36V ≤ 250 K and T36H ≤ 240 K)**

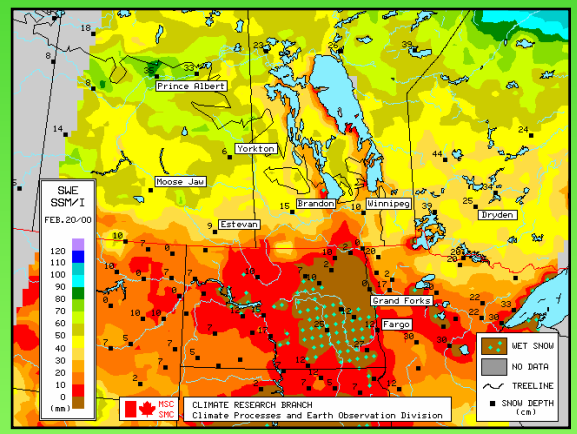
Regional SSM/I SWE Products for Research and Operational Applications



Canadian Prairies

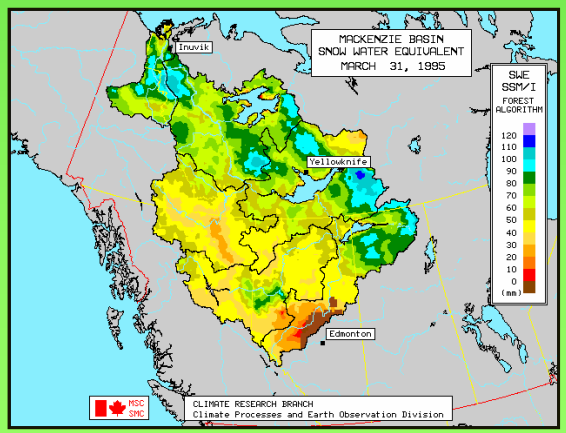
-weekly maps produced and sent to users (federal, provincial agencies, private industry) who have a requirement for regular monitoring of snow cover in western Canada

- available to public on www.socc.ca (State of Canadian Cryosphere)



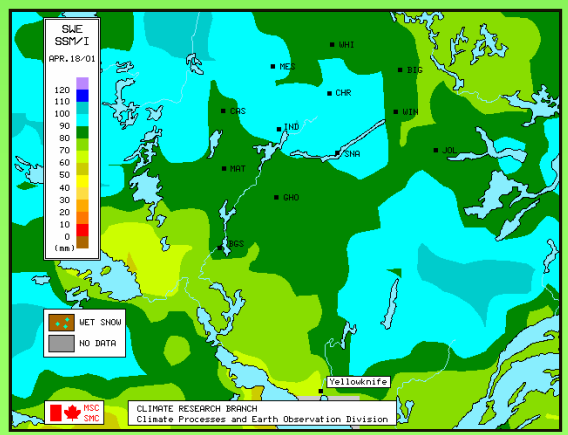
Manitoba – Red River watershed

- specialized maps sent to provincial water resource agencies focussed on priority river basins for forecasting spring runoff and flood risk



Mackenzie Basin

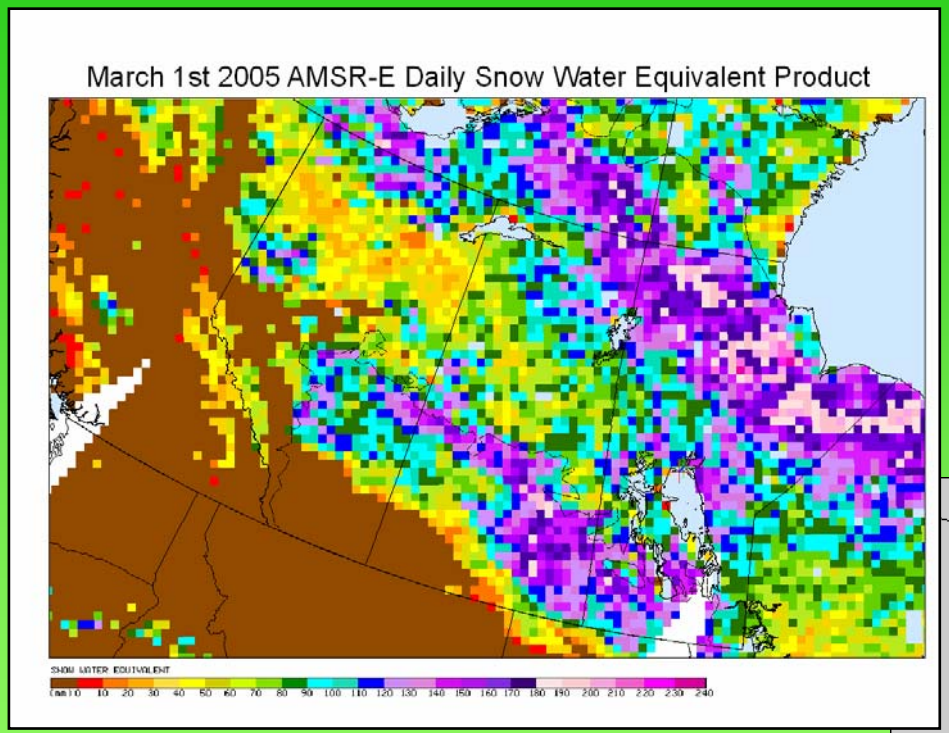
- MAGS research on snow cover variations, RCM evaluation



Snare River Basin – NWT

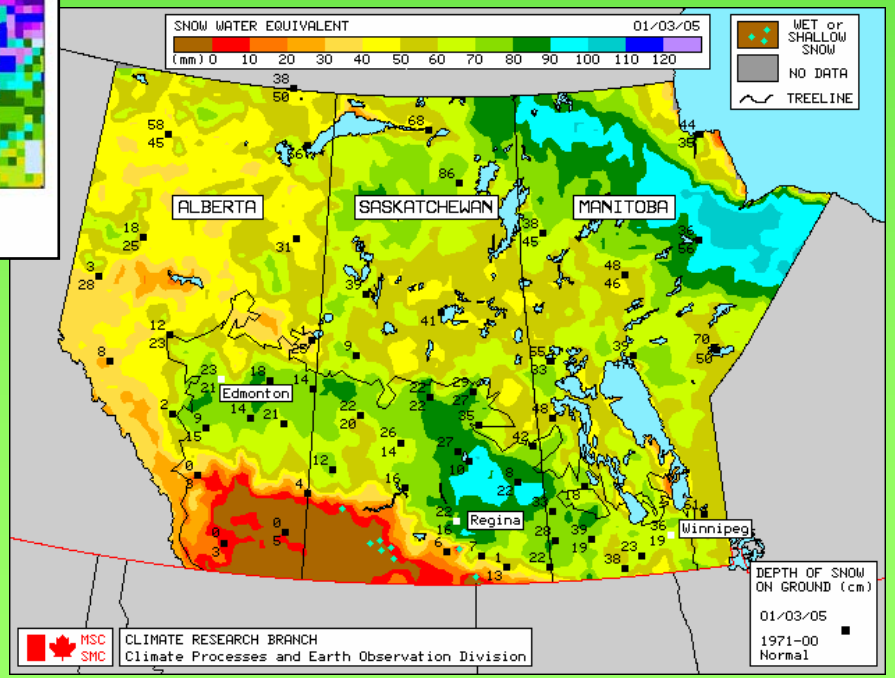
- maps for hydro companies (e.g. NWT Power Corp.) in support of planning hydroelectric power operations

Comparison with SSM/I SWE Products – Western Canada



Comparisons with MSC SSM/I SWE operational products for Canadian prairie region

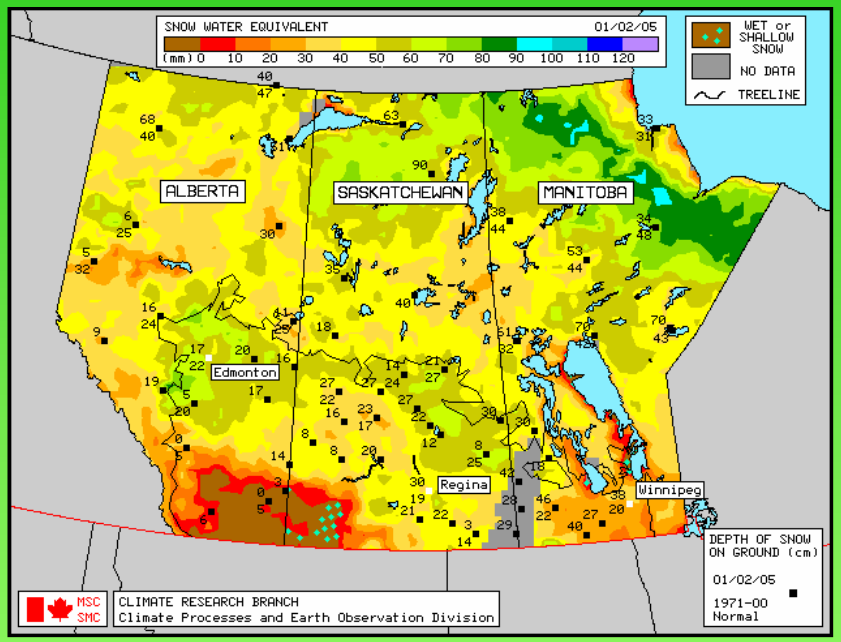
March 1, 2005



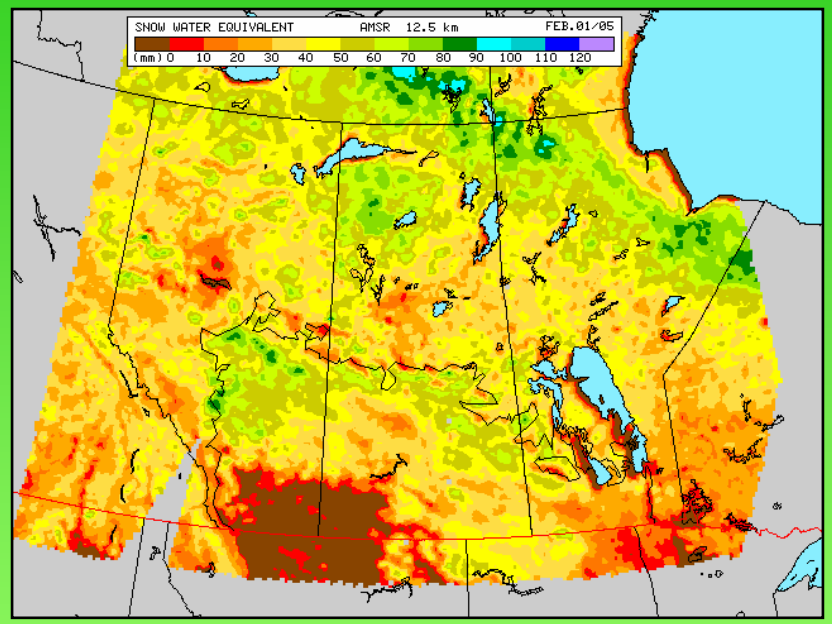
- **AMSR-E derived SWE much higher across northern Manitoba and open prairie than SSM/I derived SWE from CRB products**
- **AMSR-E derived SWE retrievals are lower through boreal forest (esp. in northern Alberta, central Sask.)**

CRB Derived SWE from AMSR-E Level 2 Data

February 1, 2005



Standard SSM/I SWE Map



AMSR-E SWE Map – CRB Algorithm

- *finer spatial resolution – more detailed SWE information*
- *AMSR-E derived SWE maps will be sent out to clients this winter for evaluation*

Ongoing/Future Work

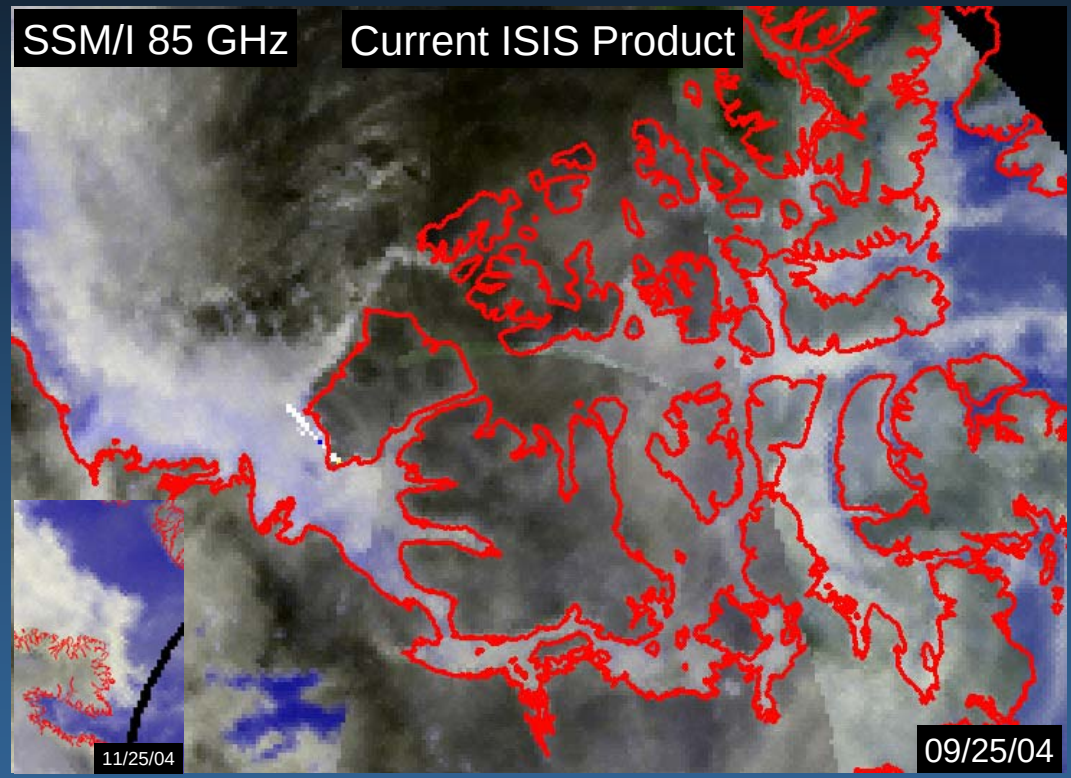
- Ongoing evaluation of AMSR-E Level 3 Daily SWE products currently available
- Evaluation of AMSR-E derived regional SWE map products by clients
- CRYSYS airborne/field campaigns planned for Spring 2006 in northern Canada towards improved SWE retrievals in tundra environments
- Validation data sets from aircraft/field campaigns will be available to scientific community via Canadian Cryospheric Information Network (CCIN) – *www.ccin.ca*
- Planning for International Polar Year (2007-2008) – validation of tundra SWE retrievals at study sites across northern Canada (airborne/field data collection)
    - *"State and Fate of the Cryosphere"* (CliC-led international IPY project)

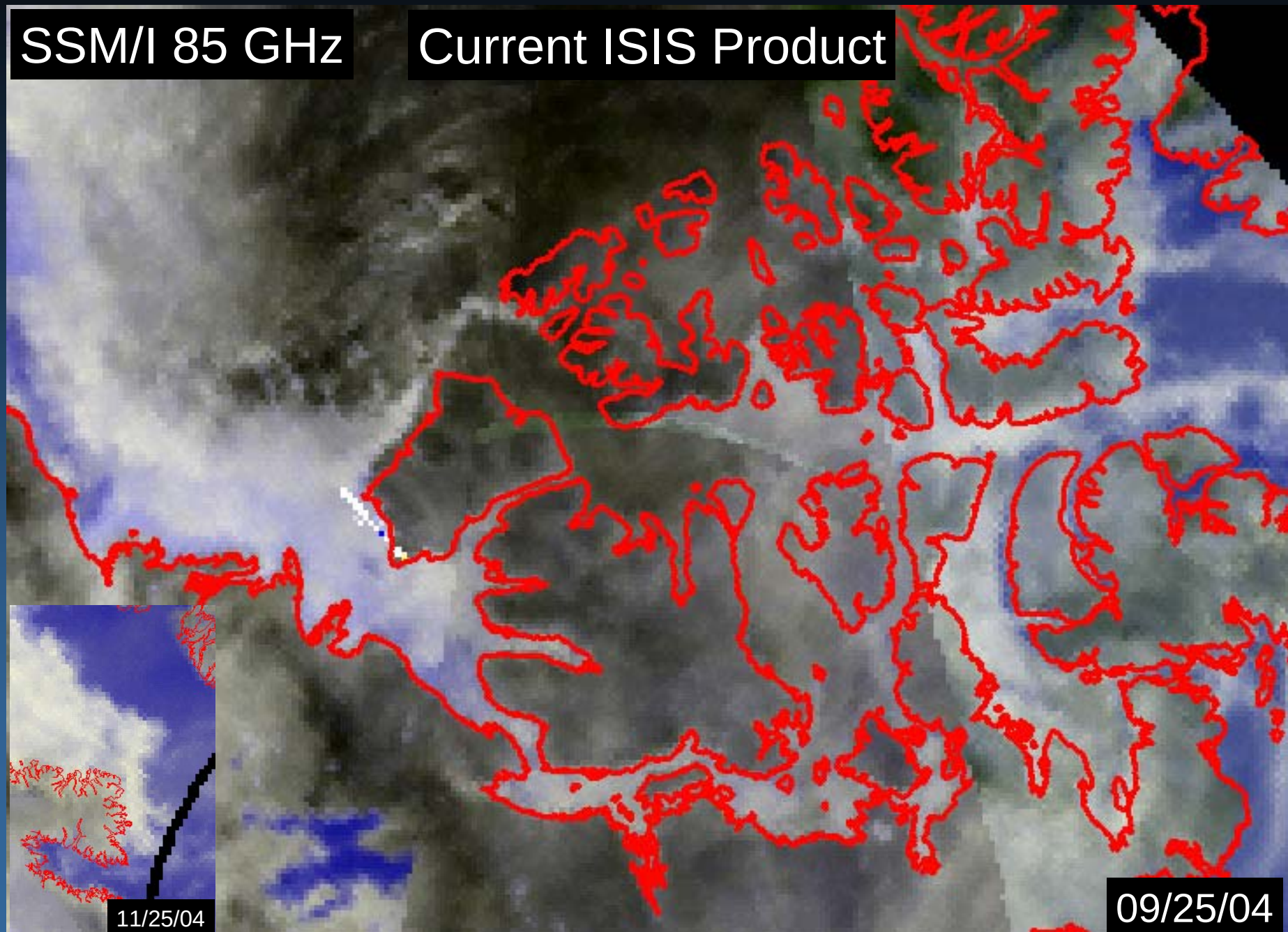
Application of AMSR-E Data/Products for Operational/Climate Sea Ice Applications

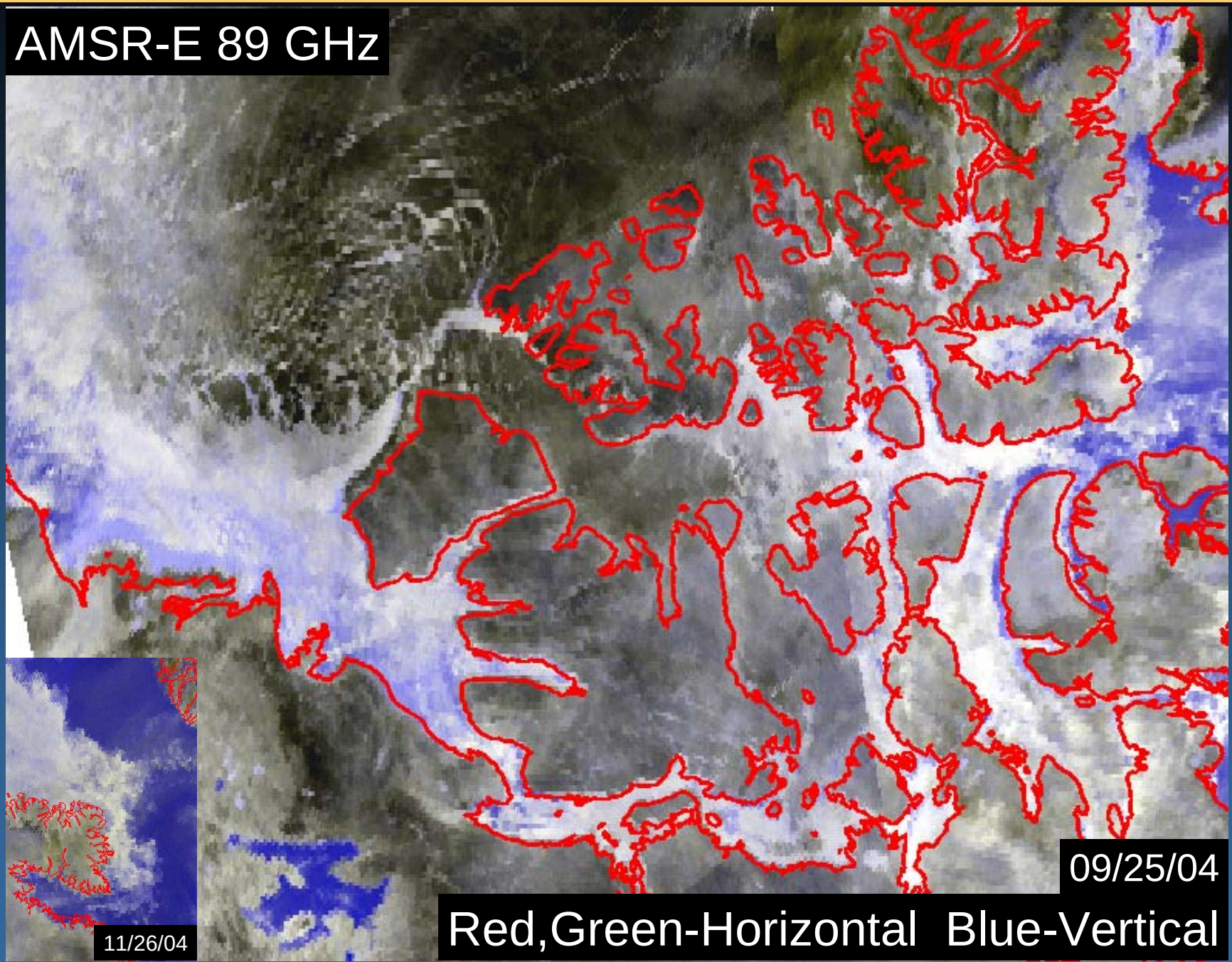
Contributors: **R. DeAbreu (Canadian Ice Service/MSC)**
T. Agnew (Climate Research Branch/MSC)

AMSR for CIS Operations

- After NOAA NESDIS started to make AMSR available in near real time, CIS became interested in dataset's operational value
- CIS Operations uses an SSM/I 85 GHz false colour composite image to support ice edge mapping on a regional scale.
- How much more information would a similar AMSR-E image product provide ?
- 3 month evaluation set up with Operations staff to assess AMSR-E and potential role it could play monitoring ice




SSM/I 85 GHz
Current ISIS Product
11/25/04
09/25/04


AMSR-E 89 GHz
11/26/04
09/25/04
Red,Green-Horizontal Blue-Vertical

Evaluation Results

- Provides more ice information than QuikSCAT and SSM/I -- primarily due to higher resolution. Unlike SSM/I, can use AMSR reliably between the arctic islands.
- Used primarily for locating the ice edge and for general ice typing (first year ice and multiyear ice).
- AMSR-E mapped ice edge close to RADARSAT (albeit at less detail).
- Availability of 10 GHz channel useful for separating ice and clouds when not obvious in 89 GHz data.
- SSM/I data should still be made available because AMSR coverage not as frequent (only one platform)
- Due to its coarser resolution, it would not be used for operational daily ice analysis, i.e. creating the daily ice chart.

Next Steps

- Further investigation into utility of other AMSR channels
- AMSR – based sea ice concentration algorithms being assessed.
- While now seen as an operationally important dataset, AMSR-E also is a core dataset to allow us to prepare for CMIS.

Canadian Archipelago Through-flow Study (CATS)

Objective: To estimate the rate of transport of freshwater through the Canadian Archipelago into Baffin Bay/Labrador Sea

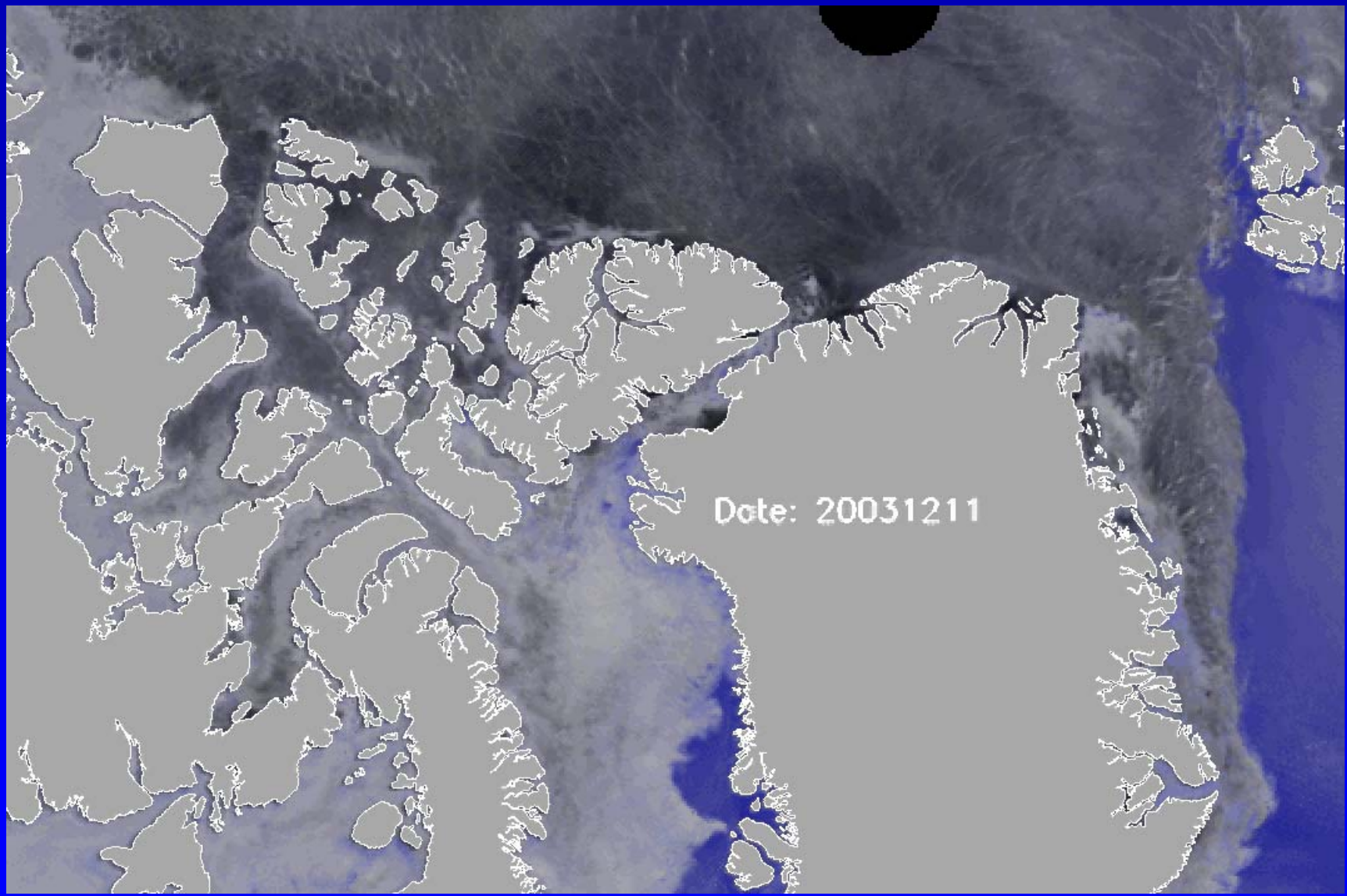
Activities

- NSF/SEARCH - 5–year funded study (2002 to 2007)
- 2003 Ocean expeditions to set up moorings (currents, salinity, ice draft, pressure, tracers)
- Remote Sensing (AMSR-E*, MODIS, AVHRR)
- Modeling (sub-mesoscale winds)

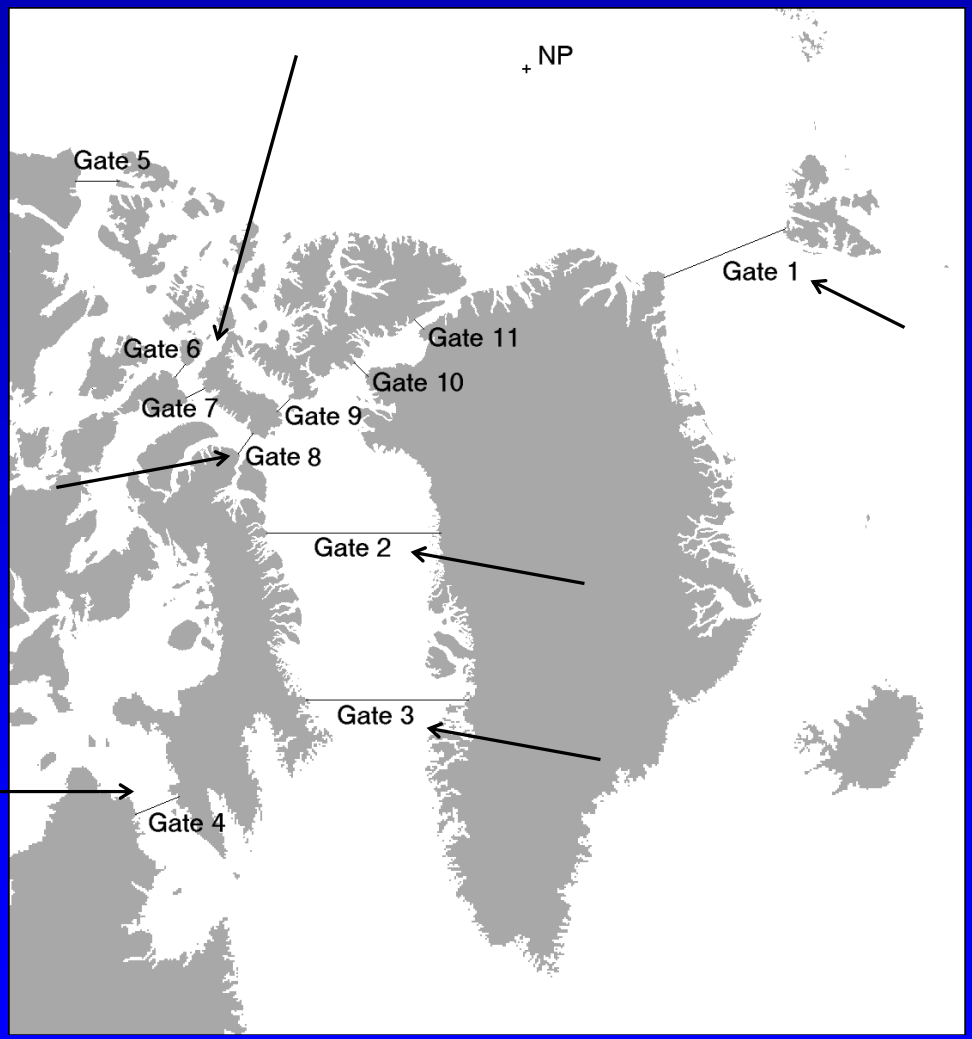
Investigators

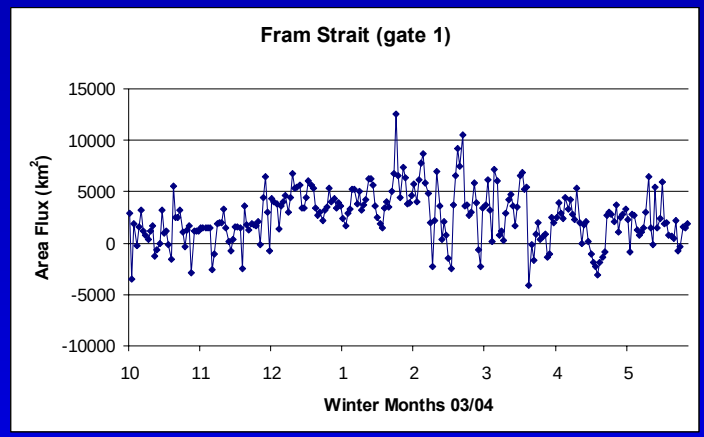
Kelly Falkner, Roger Samelson, Marta Torres, Oregon State University (OSU)
Andreas Münchow, Kuo Wong, University of Delaware (UDel)
Humfrey Melling, Fiona McLaughlin, Robie Macdonald, Eddy Carmack,
Institute of Ocean Sciences (IOS), Canada
Tom Agnew, Meteorological Service of Canada
Peter Jones, John N. Smith, Bedford Institute of Oceanography (BIO), Canada
Andrew Weaver, University of Victoria (Uvic), Canada

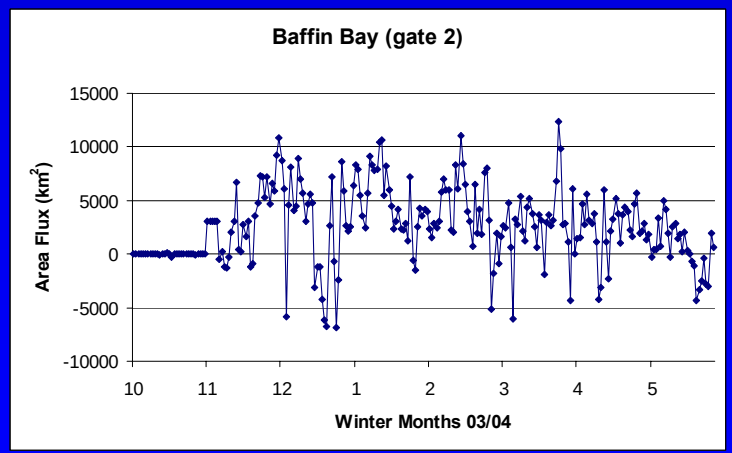
Sea ice export into the North Atlantic using AMSR-E 89 GHz



Daily Sea Ice Area Transport Across Flux Gates







Sea Ice Area Transport for Fram Strait, Baffin Bay and Davis Strait (winter 02/03 and 03/04)